WS2-4-3

Weighting Methodology for Median Ground-Motion Logic Tree Branches

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Methods for TI Team to Assign Weights for GM models

- 1. Weights for published GMPEs
- 2. Scaled backbone approach
- 3. Sammon's map approach

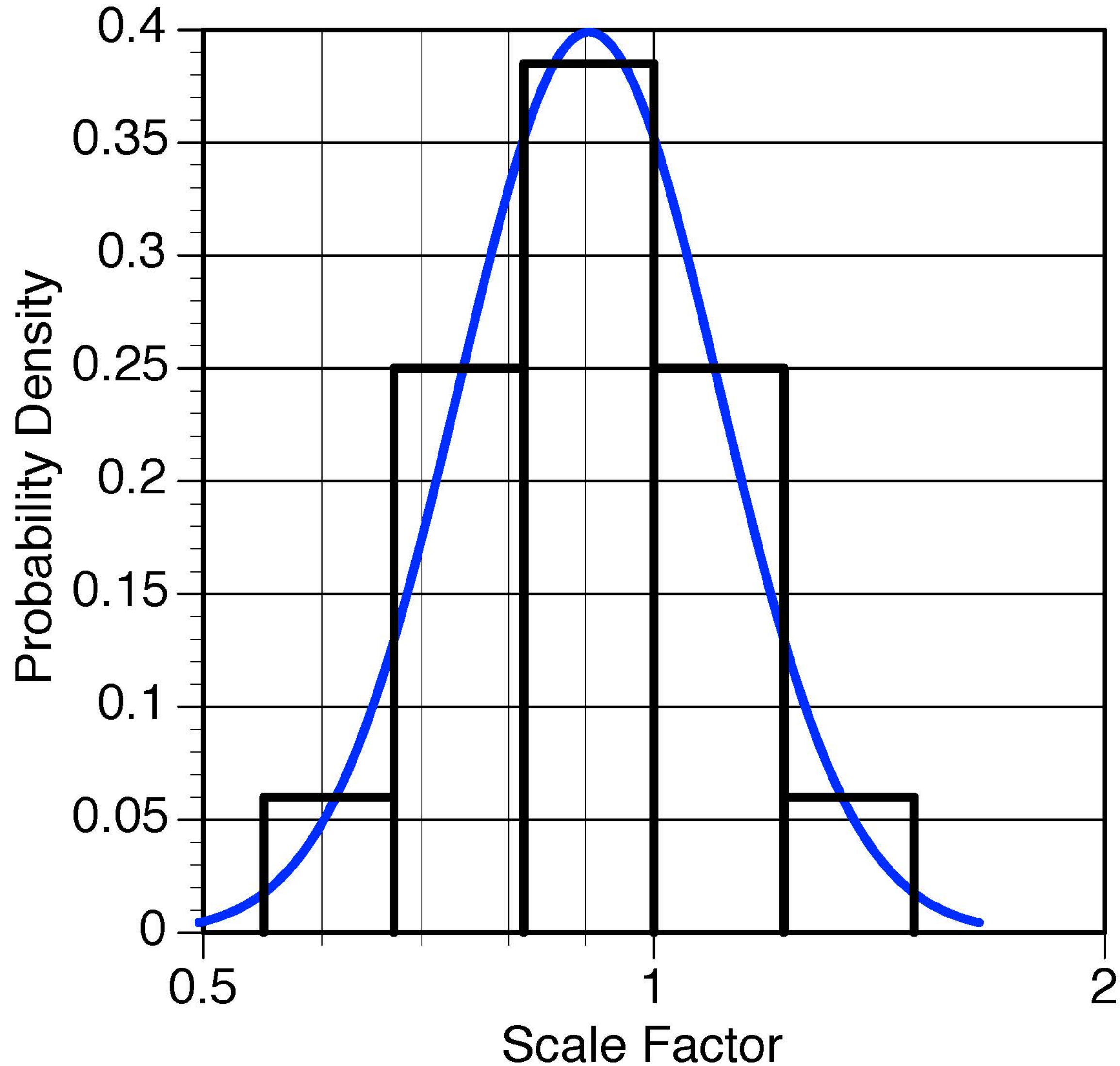
Approach 1: Weights for GMPEs

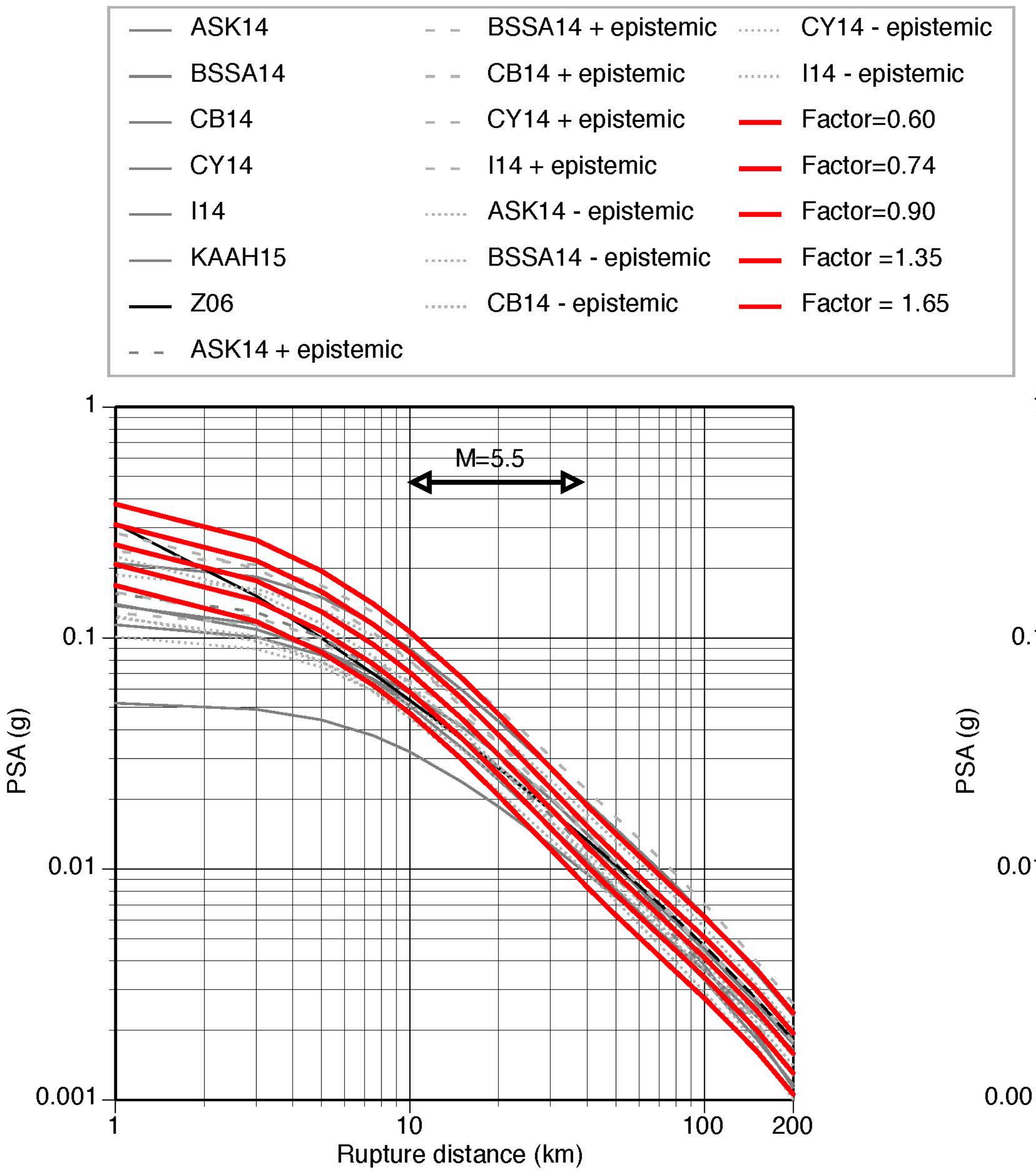
- Evaluation of the strengths and weaknesses of the alternative GMPEs
  - Size of the data set
  - Regression methodology
  - Constraints on the extrapolation
- Advantages
  - Uses published GMPEs
- Disadvantages
  - Weights represent relative merits of the models and are not probabilities
  - May not be a complete sample of possible GMPEs

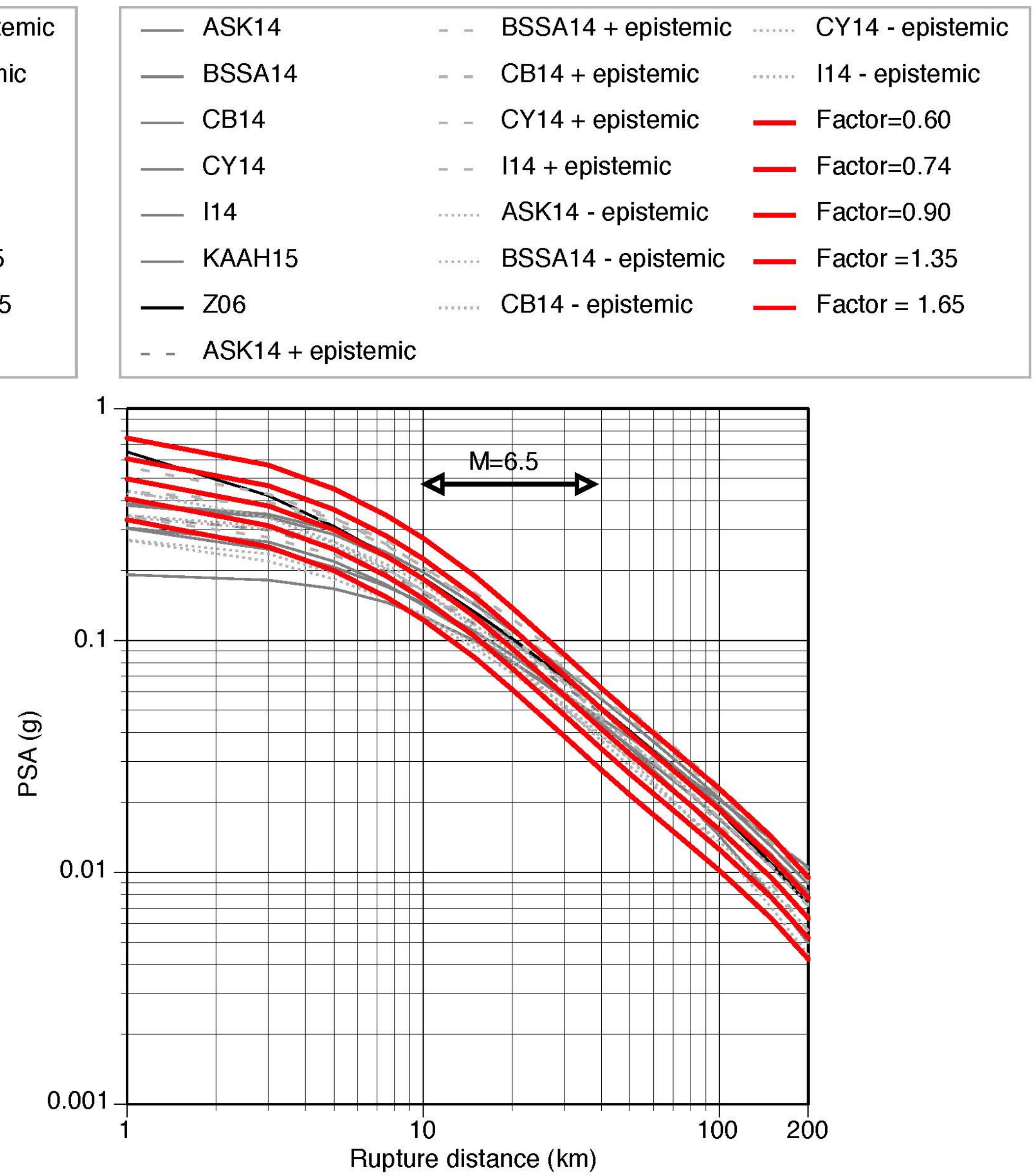
Approach 2 – Scaled Backbone

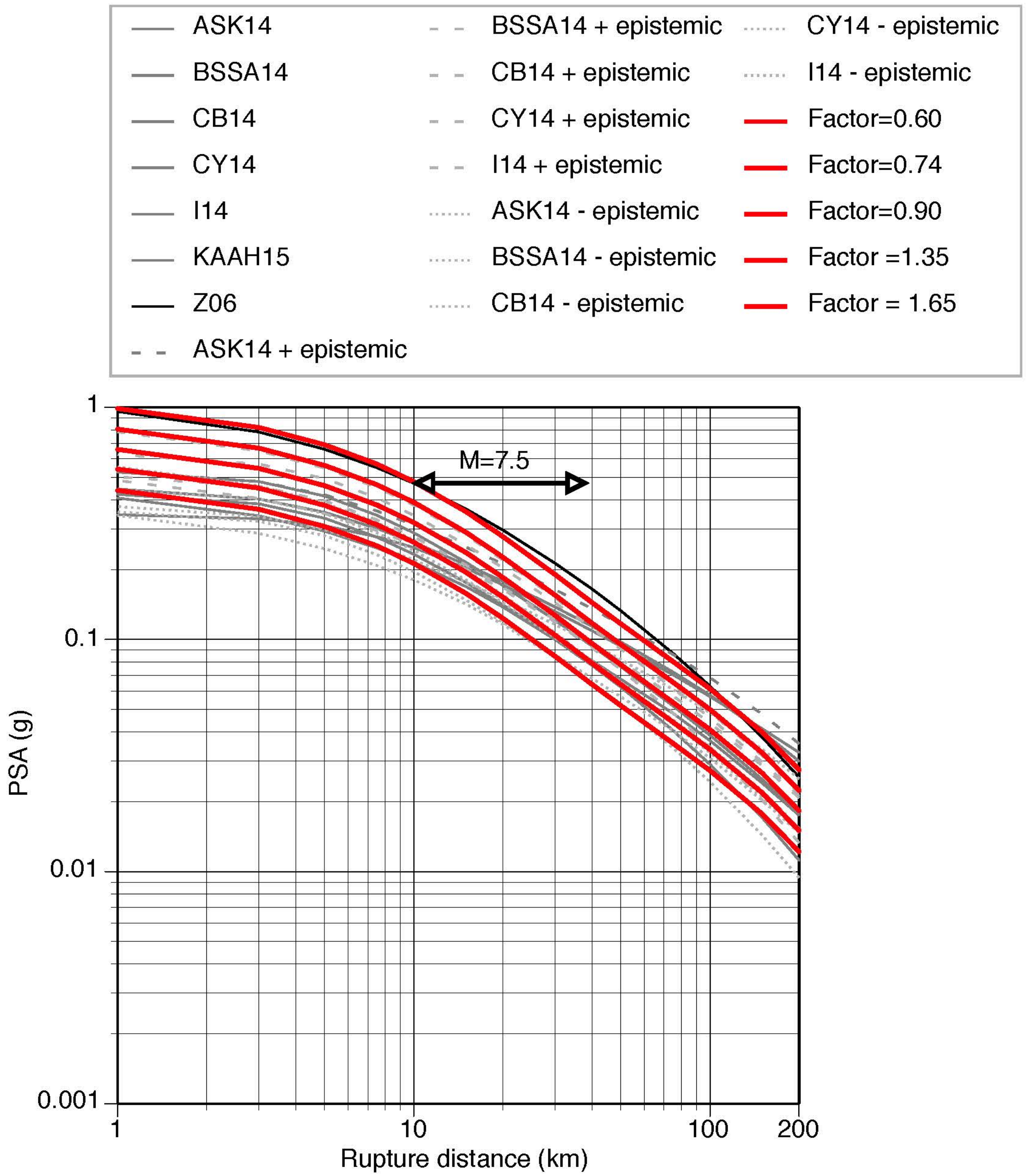
- Select a representative GMPE that is applicable to the specific application
  - The model should extrapolate in a reasonable manner
- Find scale factors that sample the range of the candidate GMPEs (plus additional epistemic if needed)
- The range of scale factors provides a continuous distribution of GMPEs
- Scaled GMPE
  - Mutually exclusive (ME)
  - Collectively exhaustive (CE)
- Discretize distribution of scale factors to get branches for the logic tree

Discretized Backbone Scale Factors (apply to all M & R)




ASK14
BSSA14
CB14
CY14
I14
KAAH15
Z06
ASK14 + epistemic
BSSA14 + epistemic
CB14 + epistemic
CY14 + epistemic
I14 + epistemic
ASK14 - epistemic
BSSA14 - epistemic
CB14 - epistemic
CY14 - epistemic
I14 - epistemic
Factor=0.60
Factor=0.74
Factor=0.90
Factor =1.35
Factor = 1.65
M=5.5
PSA (g)
1
0.1
0.01
0.001
1
10
100
200
Rupture distance (km)


ASK14
BSSA14
CB14
CY14
I14
KAAH15
Z06
ASK14 + epistemic
BSSA14 + epistemic
CB14 + epistemic
CY14 + epistemic
I14 + epistemic
ASK14 - epistemic
BSSA14 - epistemic
CB14 - epistemic
CY14 - epistemic
I14 - epistemic
Factor=0.60
Factor=0.74
Factor=0.90
Factor =1.35
Factor = 1.65
M=6.5
PSA (g)
1
0.1
0.01
0.001
1
10
100
200
Rupture distance (km)



ASK14
BSSA14
CB14
CY14
I14
KAAH15
Z06
ASK14 + epistemic
BSSA14 + epistemic
CB14 + epistemic
CY14 + epistemic
I14 + epistemic
ASK14 - epistemic
BSSA14 - epistemic
CB14 - epistemic
CY14 - epistemic
I14 - epistemic
Factor=0.60
Factor=0.74
Factor=0.90
Factor =1.35
Factor = 1.65
M=7.5
PSA (g)
1
0.1
0.01
0.001
1
10
100
200
Rupture distance (km)

Scaled Backbone Approach

- Advantages
  - Easy to implement
  - Produces a set of GMPEs that are MECE
  - Mutually exclusive and collectively exhaustive
    - Weights for logic tree branches are probabilities
- Disadvantages
  - Does not maintain the magnitude and distance scaling differences in the published GMPEs
  - A single scale factor may not capture the scaling in the other GMPEs over a wide range of magnitudes and distances

Sammon's Map Approach

Add a second parameter for setting the distribution of the models

- Advantages
  - Mutually exclusive and collectively exhaustive so the weights are probabilities
  - Includes some differences in magnitude and distance scaling represented in the published GMPEs
  - Objective method to assign weights
    - Given data set and statistic for weights
- Disadvantages
  - Not well understood
  - More difficult to implement
  - Using only two dimensions, so it does not capture all of the differences in the magnitude, distance, and SOF scaling in the published GMPEs

Approach 3: Sammon's maps

- Key Concept
  - Define a metric that measures the differences between two GMPEs
    - Use the weighted standard deviation of the differences in the LN (PSA) values

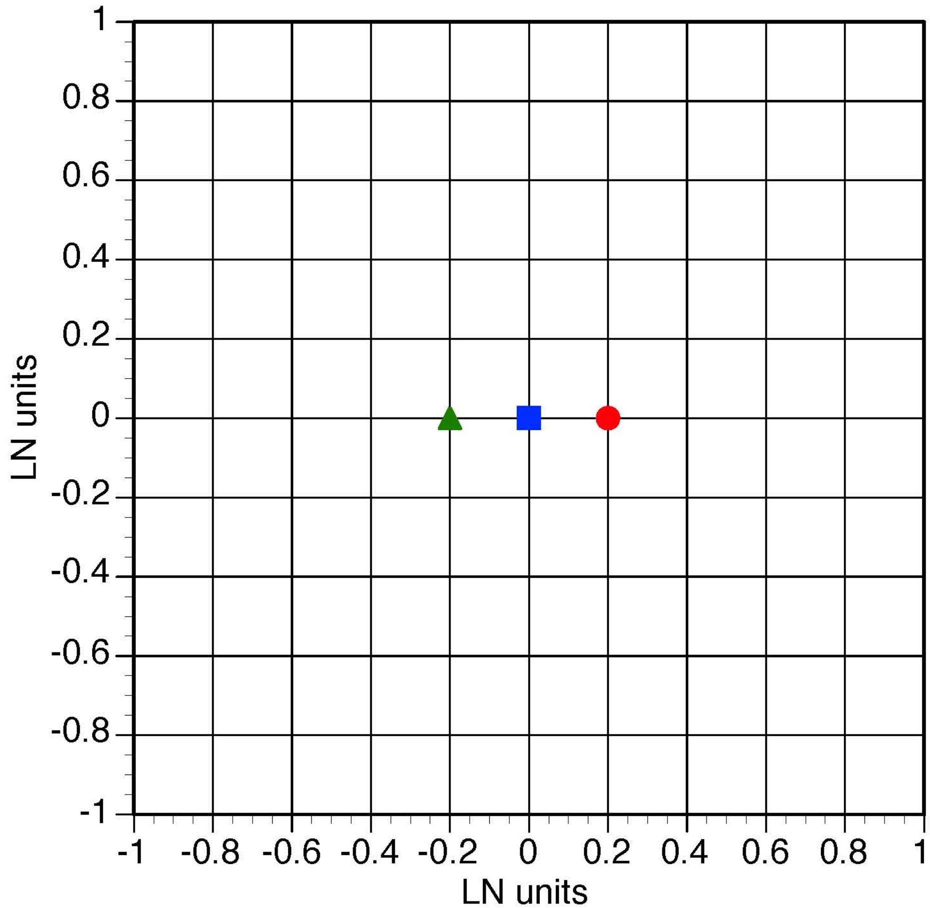
$$\Delta_{jk} = \sqrt{\frac{1}{\sum_{i=1}^{NS} wt_i} \sum_{i=1}^{NS} wt_i \left(\ln(PSA_j(M_i, R_i)) - \ln(PSA_k(M_i, R_i)) \right)^2}$$

  - Weights reflect the significance of scenario to hazard at the site
  - Plot the GMPEs on a map in which the distance between 2 GMPEs on the map is approximately equal to the Δ_{jk}

Conventions for Ground-Motion Sammon's Maps

- For consistent maps, use the following convention
  - Center on the average GMPE
  - Positive x direction is scaling up
  - Stronger magnitude scaling is in y>0 quadrant.
    - This is not the y-direction itself,

Graphical Construction of Sammon's maps: Step 1

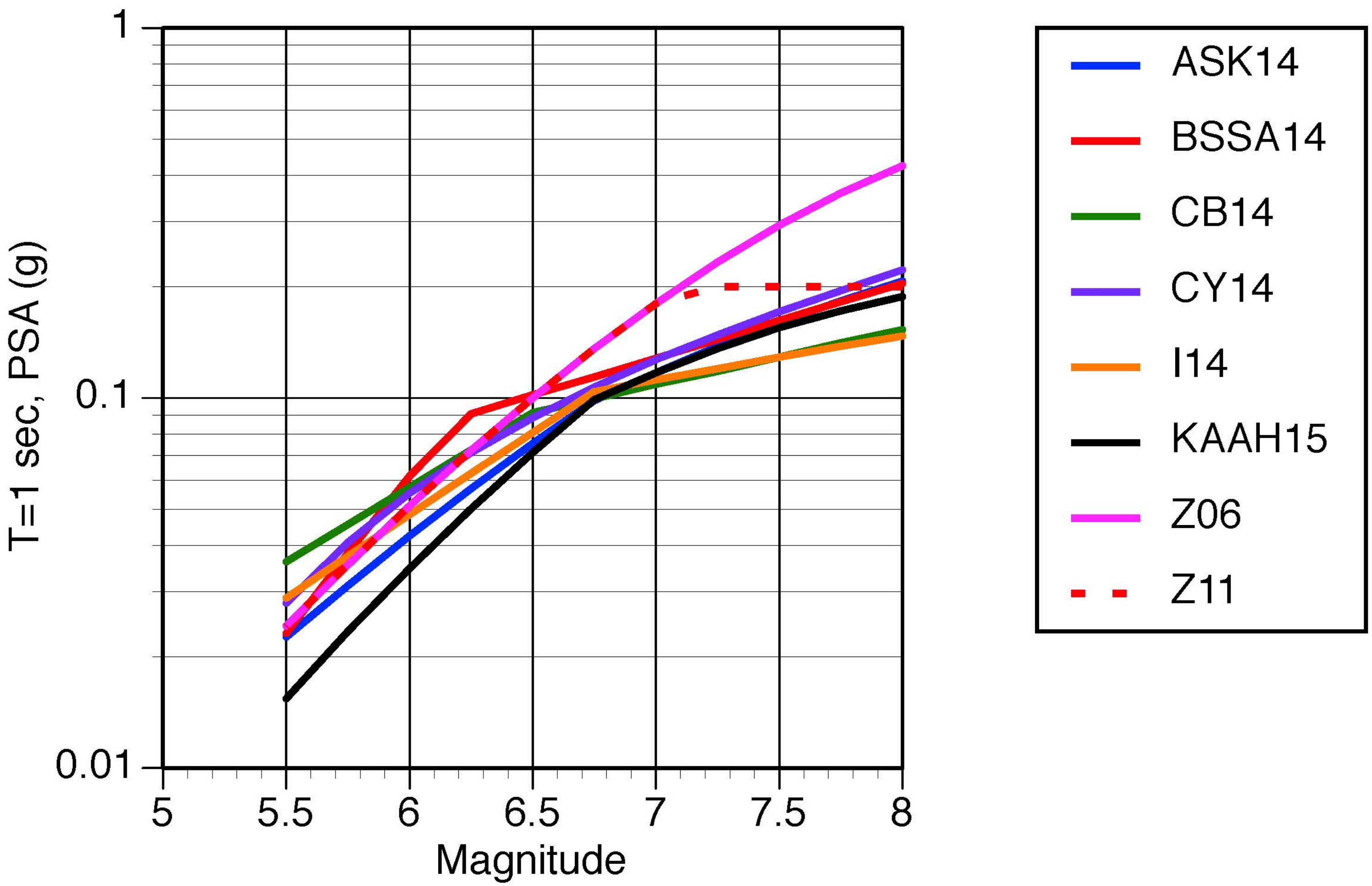


- Compute the average GMPE
- Set the map location of average GMPE to be at (0,0)
- Compute scaled versions of the average GMPE
  - Here used +- 0.2 ln units

Compute the Δ_{jk} for each pair of GMPEs

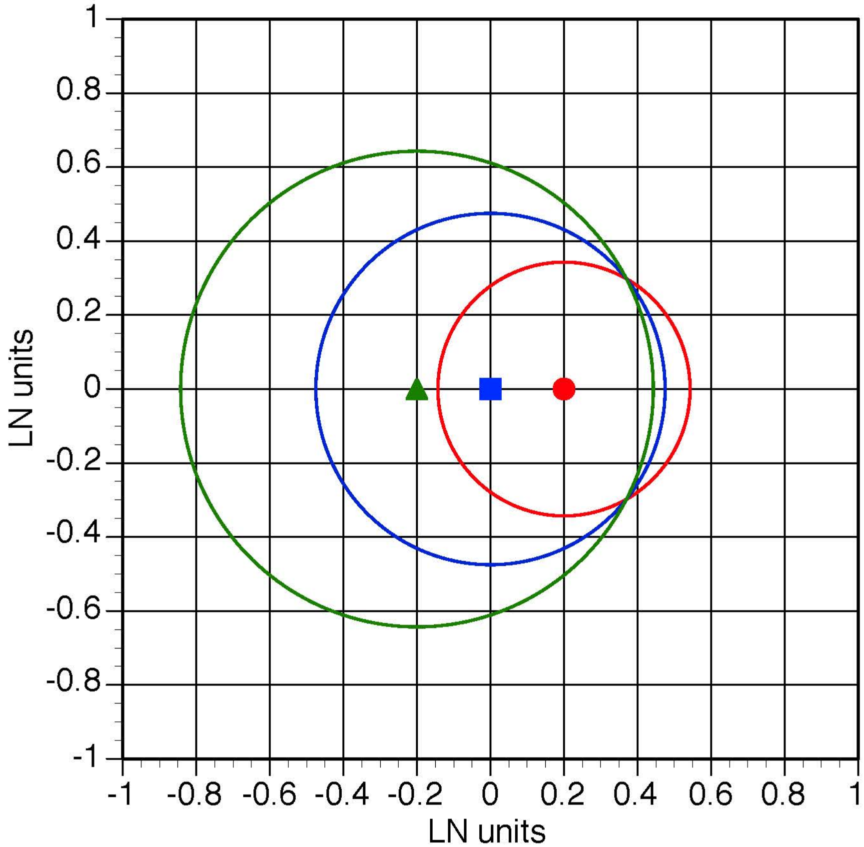
	1 (Ave)	2 (ave scaled up)	3 (ave scaled down)	4 (Z06)	5 (ASK14)	6 (BSSA14)	7 (CB14)	….
1 (ave)	0	0.2	0.2	0.475	0.184	0.142	0.142	
2		0	0.4	0.343	0.287	0.171	0.255	
3			0	0.643	0.255	0.302	0.236	
4				0	0.448	0.442	0.571	
5					0	0.257	0.307	
6						0	0.225	
7							0	
…								

Magnitude Scaling



Step 2:

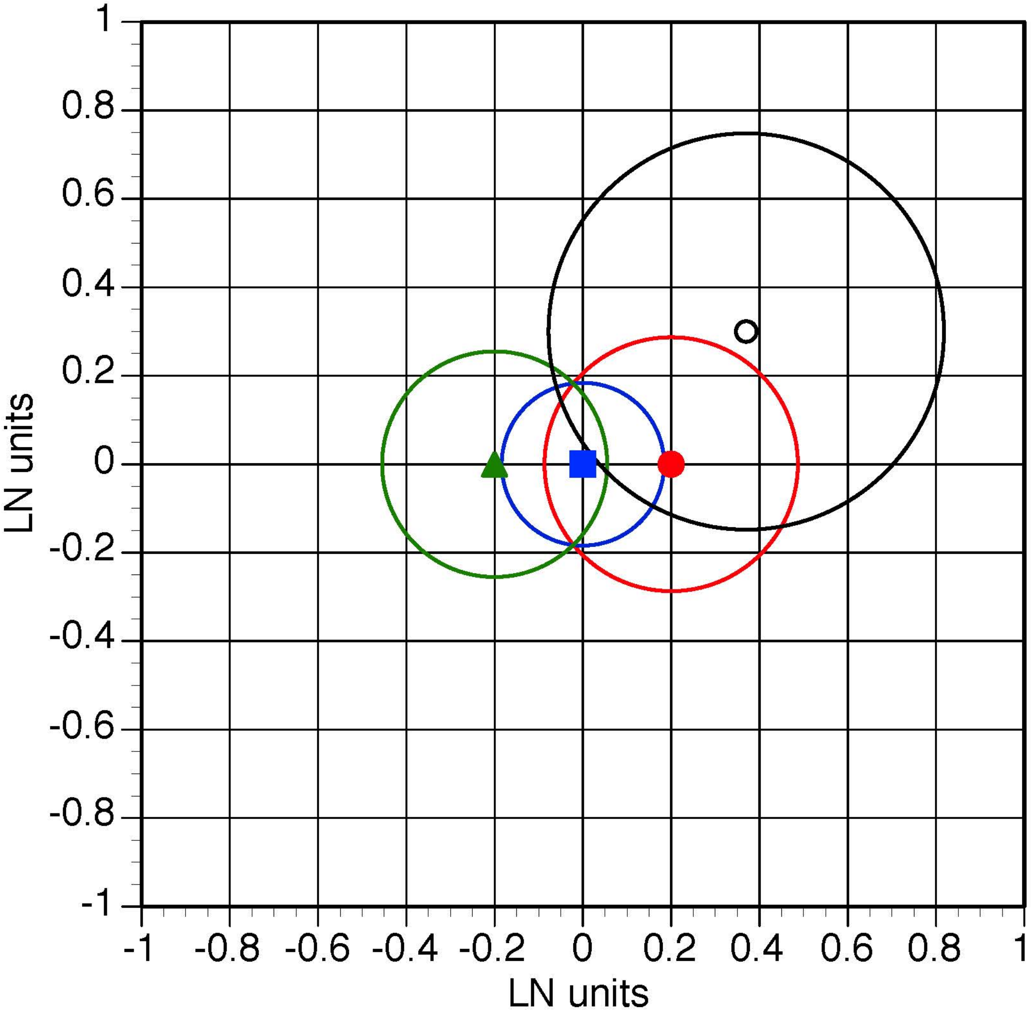
- Choose GMPE with stronger Mag scaling (can use modified average model with stronger M scaling)
- Choose the intersection in the upper half of the plot
  - This will be the direction of stronger mag scaling



Δ_{jk}

	1 (Ave)	2 (ave scaled up)	3 (ave scaled down)	4 (Z06)	5 (ASK14)	6 (BSSA14)
1	0	0.2	0.2	0.475	0.184	0.142
2		0	0.4	0.343	0.287	0.171
3			0	0.643	0.255	0.302
4				0	0.448	0.442
5					0	0.257
6						0

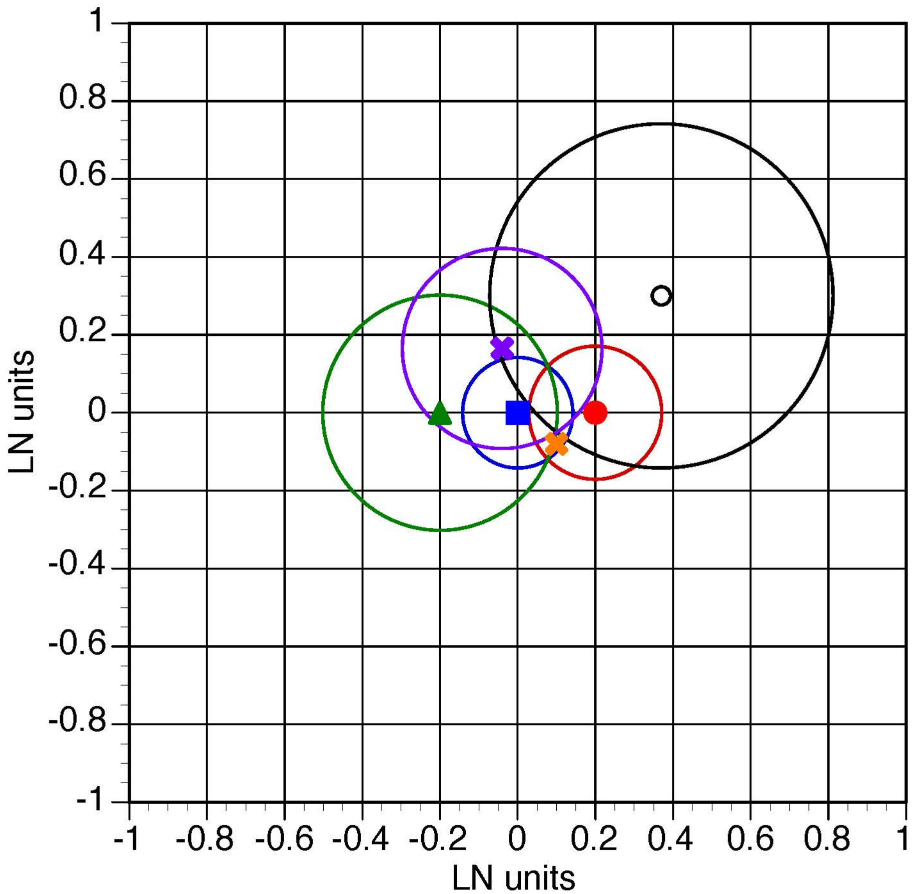
Step 3



Δ_{jk}

	1 (Ave)	2 (ave scaled up)	3 (ave scaled down)	4 (Z06)	5 (ASK14)	6 (BSSA1 4)
1	0	0.2	0.2	0.475	0.184	0.142
2		0	0.4	0.343	0.287	0.171
3			0	0.643	0.255	0.302
4				0	0.448	0.442
5					0	0.257
6						0

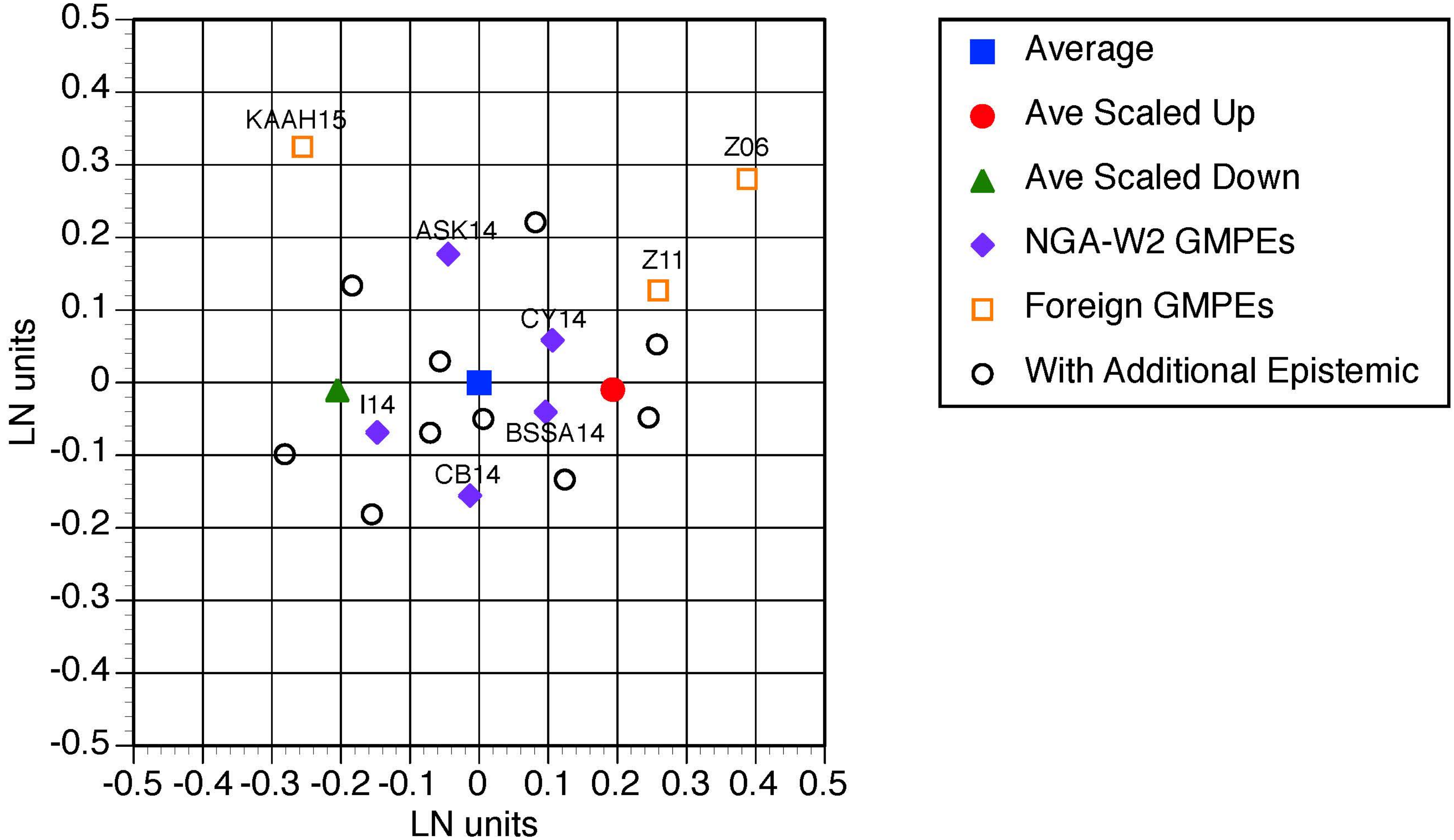
Step 4



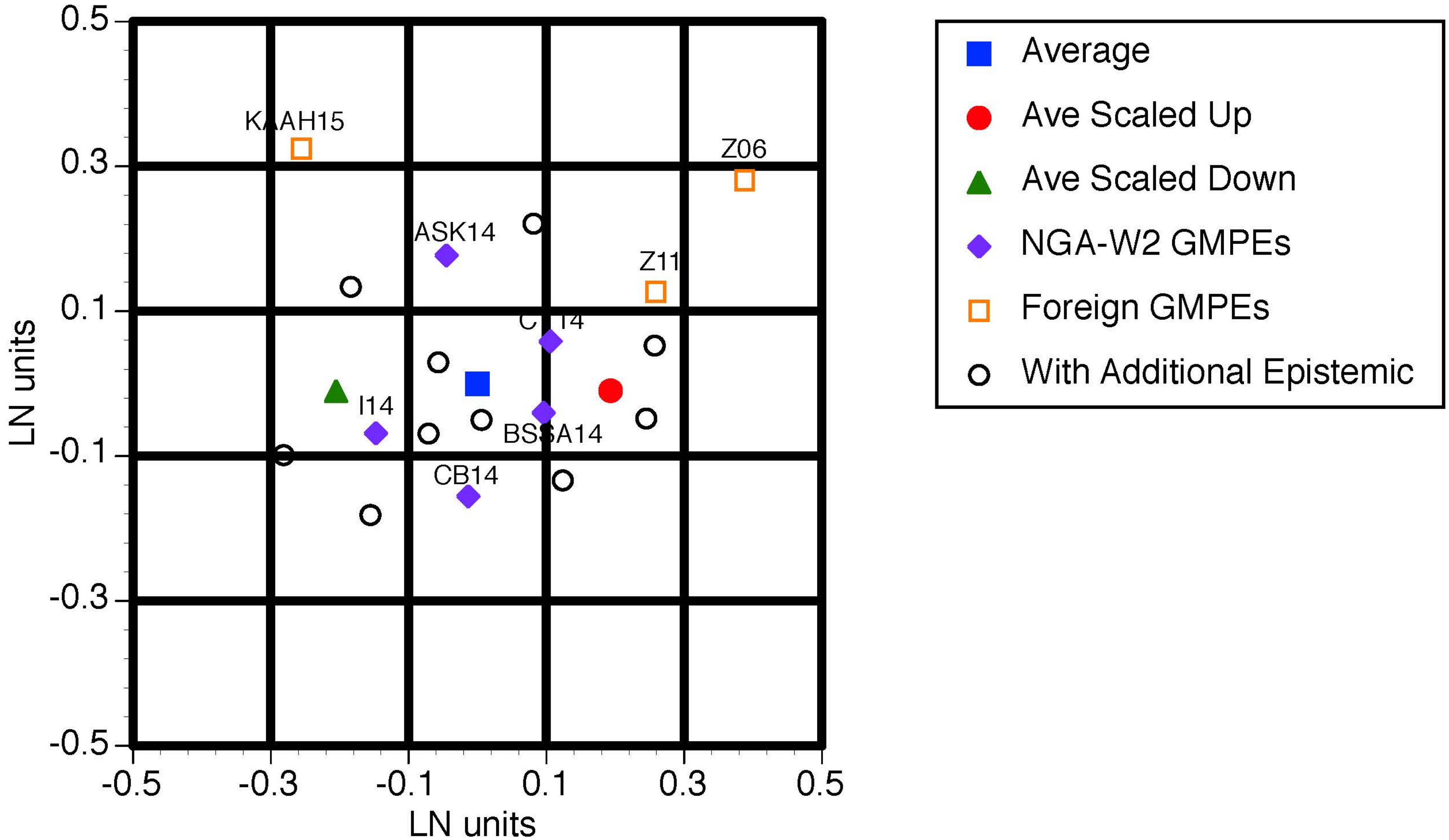
Δ_{jk}

	1 (Ave)	2 (ave scaled up)	3 (ave scaled down)	4 (Z06)	5 (ASK14)	6 (BSSA14)
1	0	0.2	0.2	0.475	0.184	0.142
2		0	0.4	0.343	0.287	0.171
3			0	0.643	0.255	0.302
4				0	0.448	0.442
5					0	0.257
6						0

Final Sammon's Map (for single T)
(Note: map depends on wts for scenarios)



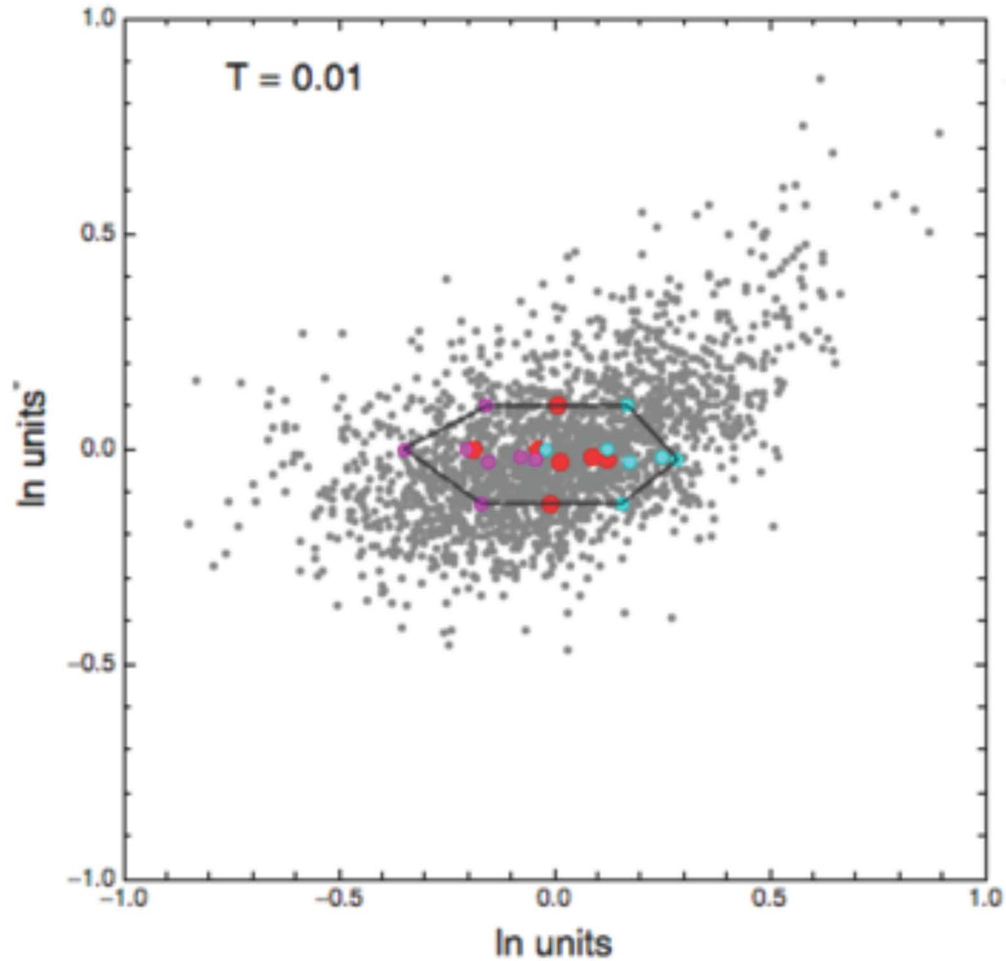
Discretize Sammon's space (MECE)



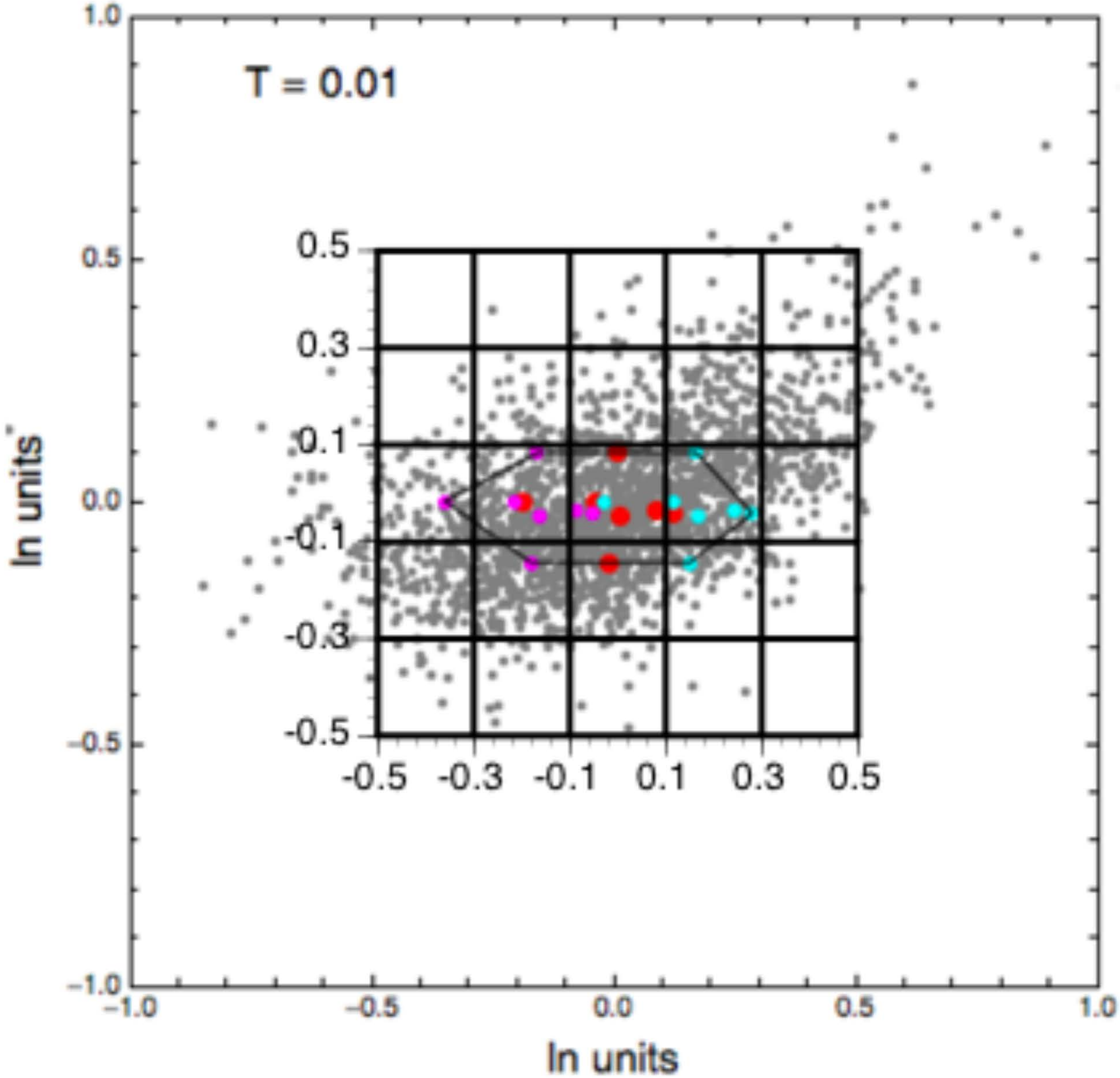
DCPP Example

Generate New GMPEs

- Expand set of GMPEs to fill in the Sammon's space
- Sample the covariance of the GMPEs (equal weights of the selected candidate models)



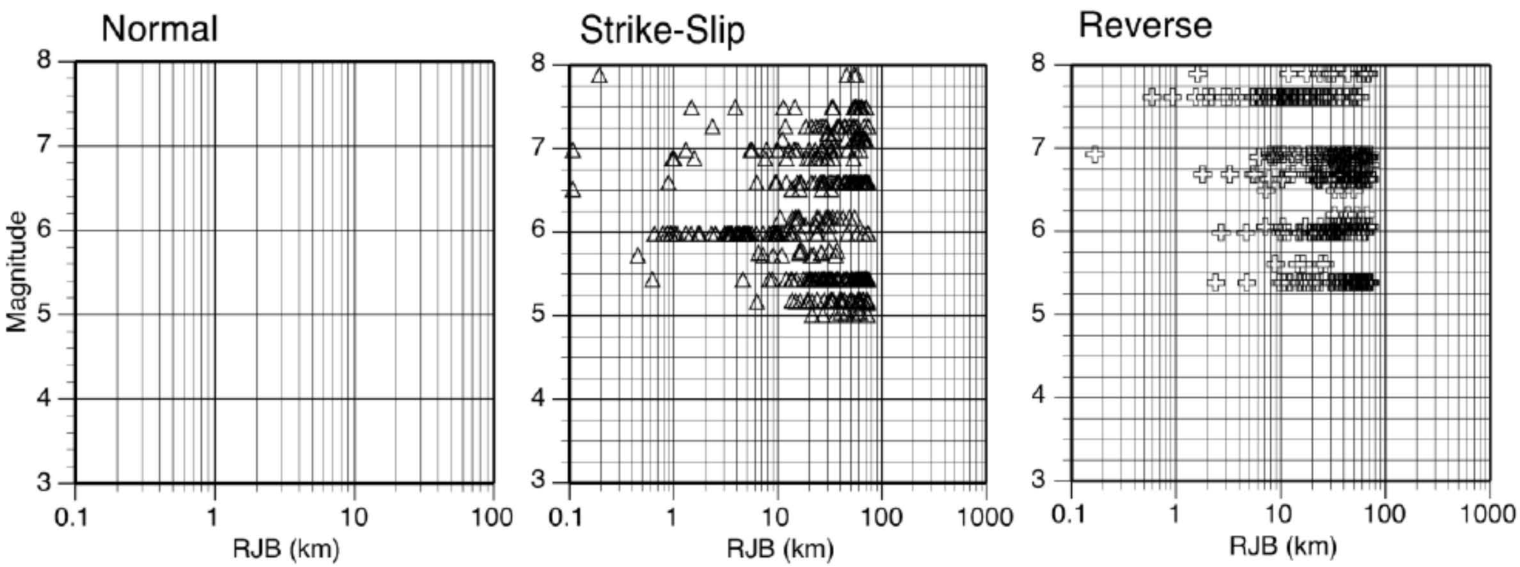
Discretize Space



Set Weights for cells

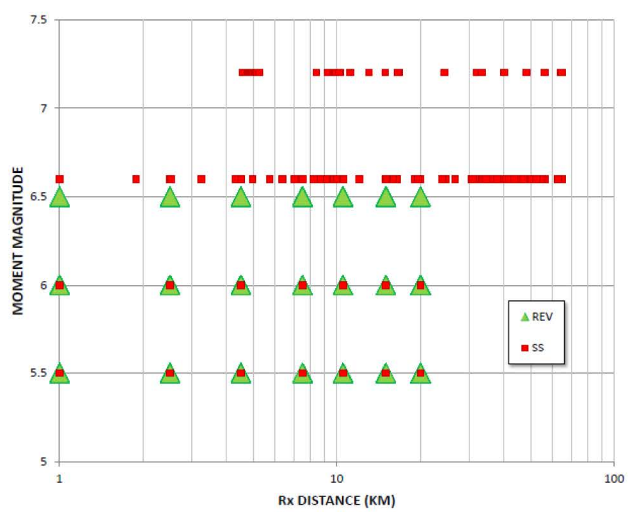
- Select representative data sets
  - Compute the mean residual for the generated GMPEs within each cell
  - Compute the likelihood for the generated GMPEs within each cell
  - Plot contours of the mean residual and log-likelihood on the Sammon's map

DCPP Example:
Data Subsets Used for To Evaluate Weights



NGA-W2
M>5, R<50

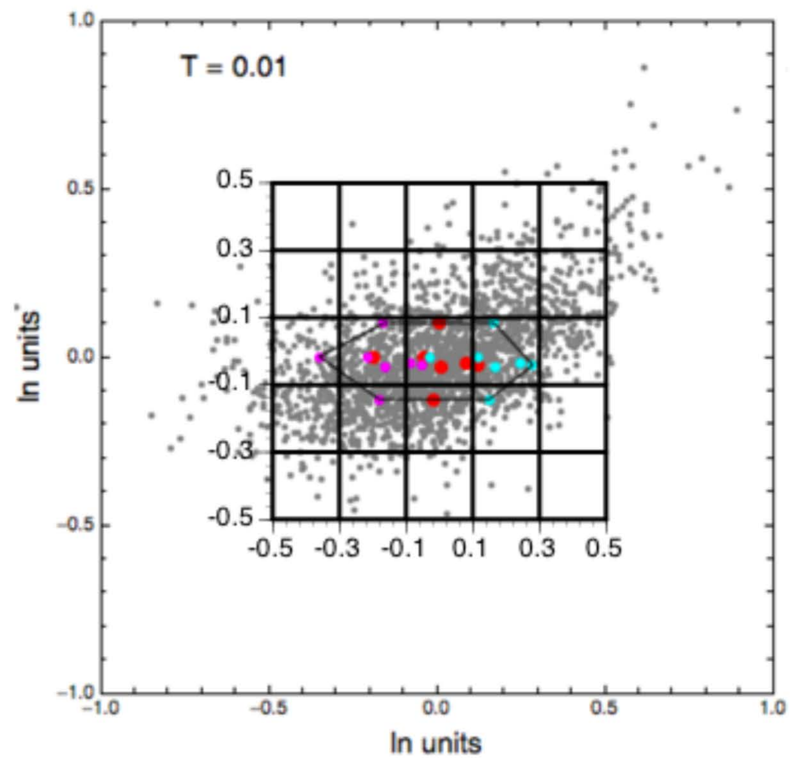
FW only
for Rev



SIMULATIONS

Approach to Assigning Weights

- Alternative statistics for setting Weights
  - 1 / | Mean event term + C |
  - Likelihood
  - Prior. Fraction of common form models that fall into a cell. (Implies equal weights to candidate GMPEs)



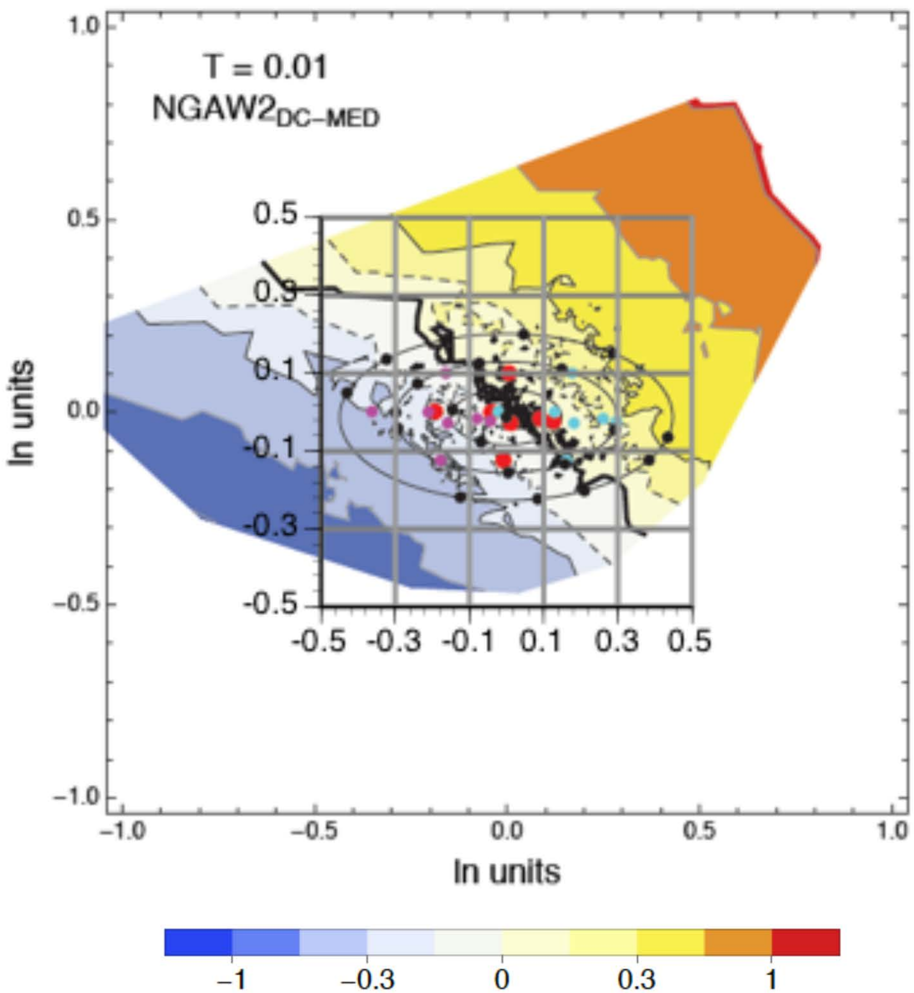
For Cell i, with Area, A_i

$$w_i = A_i \frac{1}{N_i} \sum_{j=1}^{N_i} L_{ij}$$

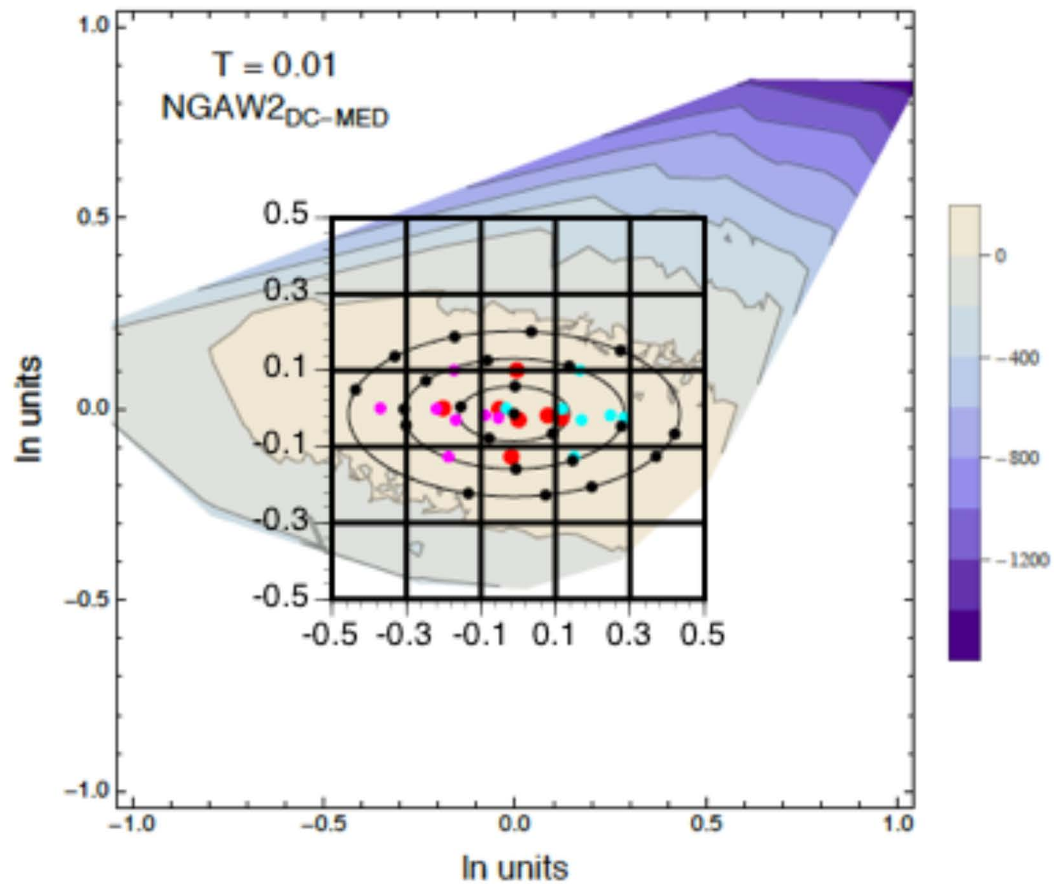
Then, renormalize weights to sum to unity

Using CA data set

Mean Abs(Event Term)

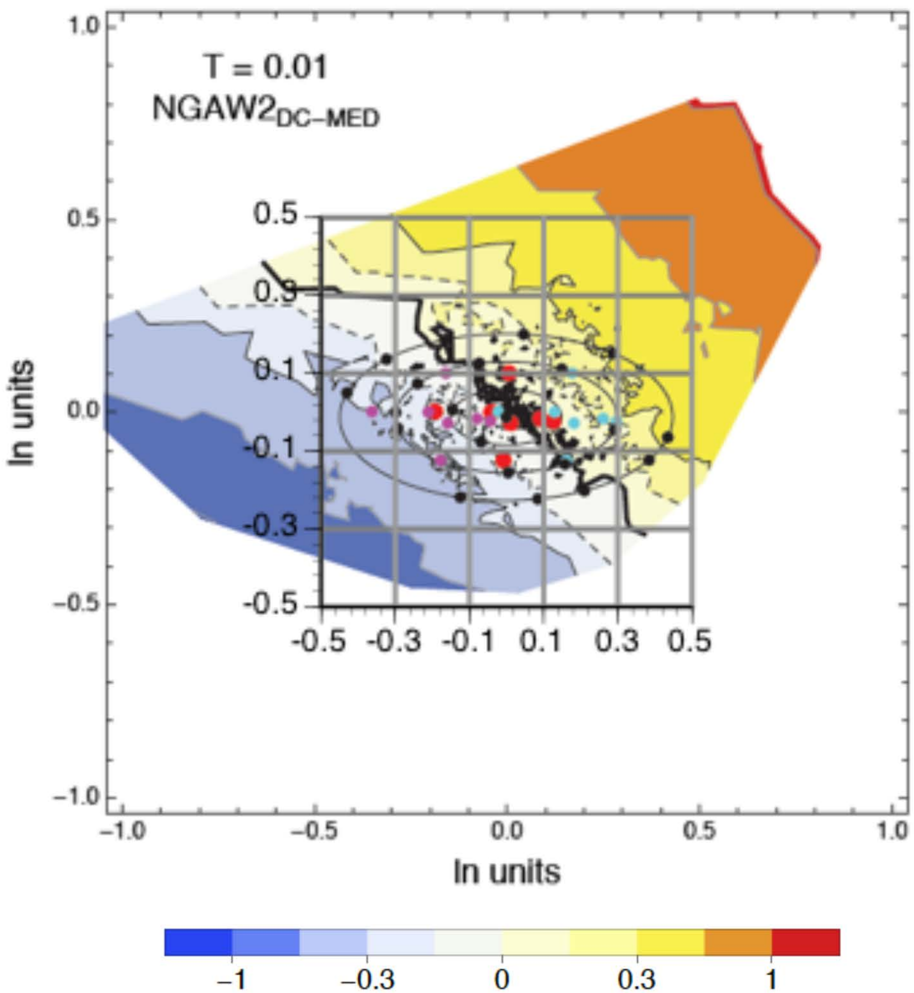


Likelihood

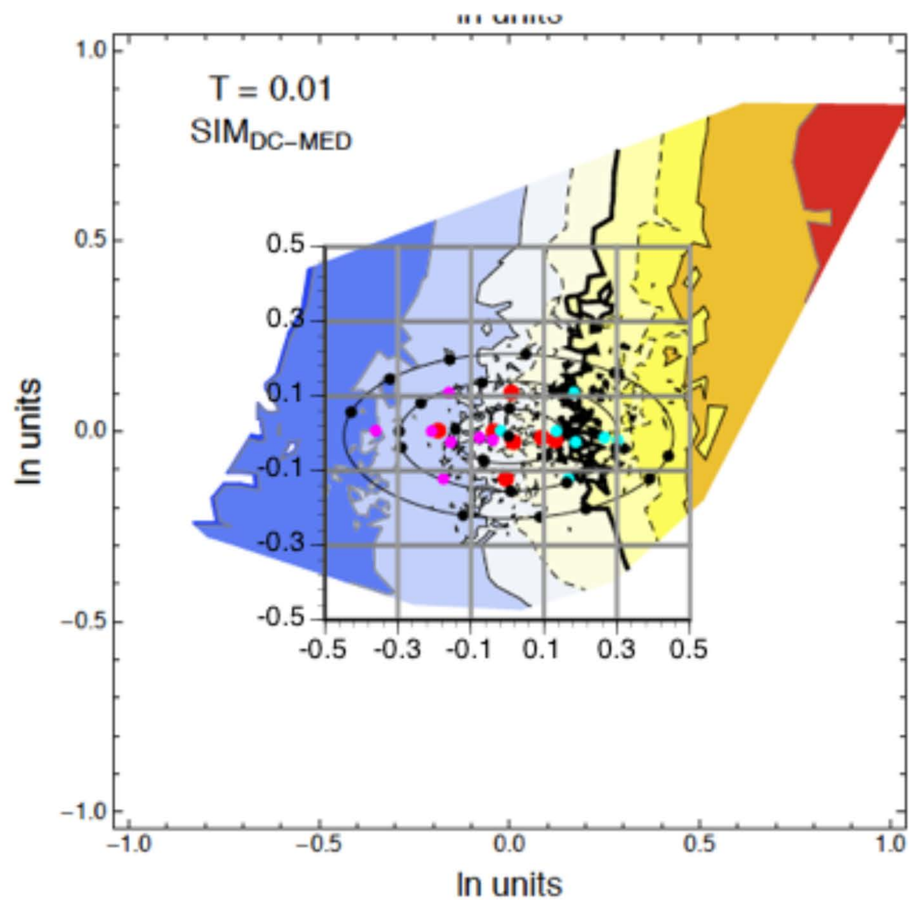


Comparison for different data sets

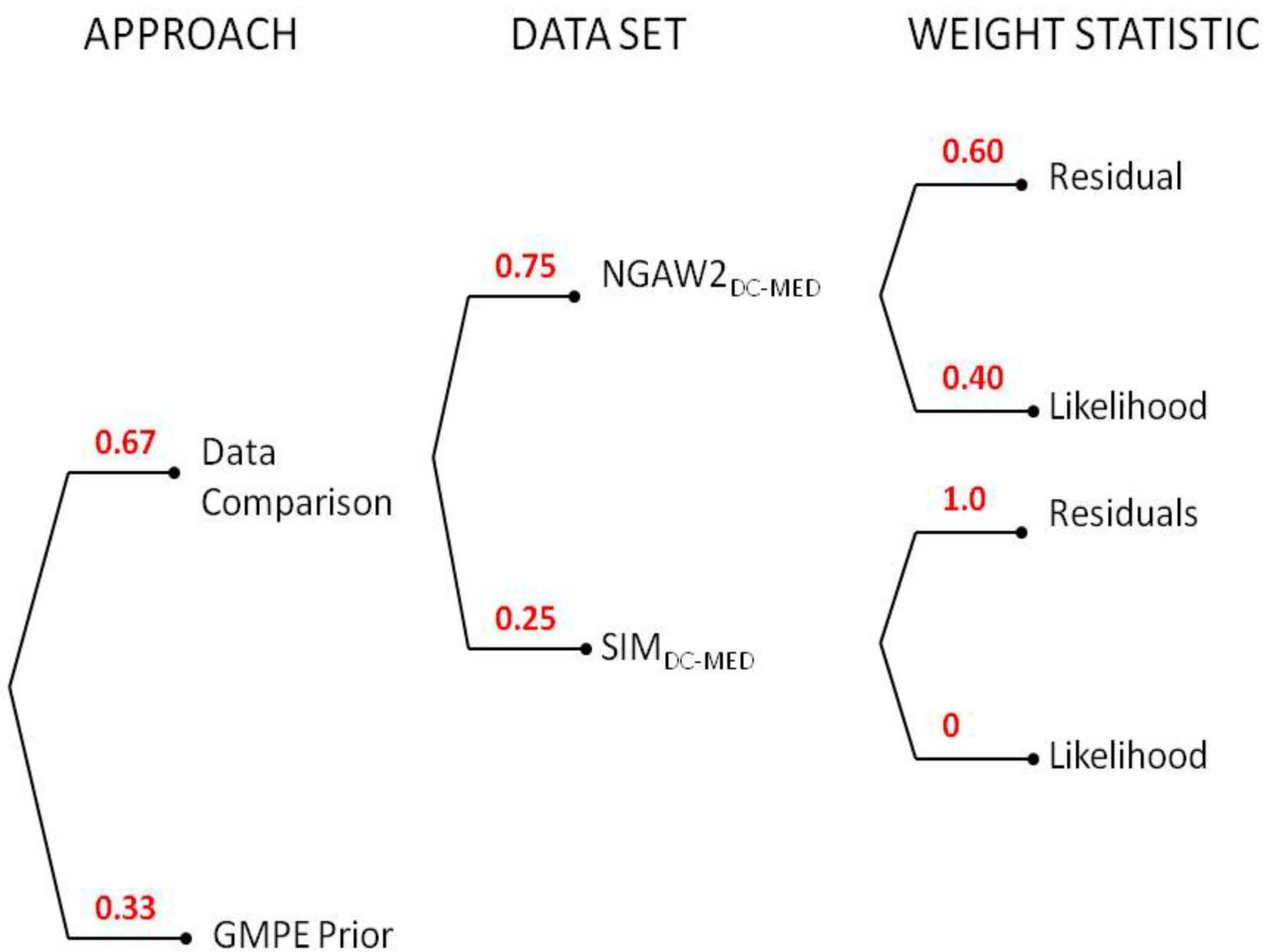
CA Data



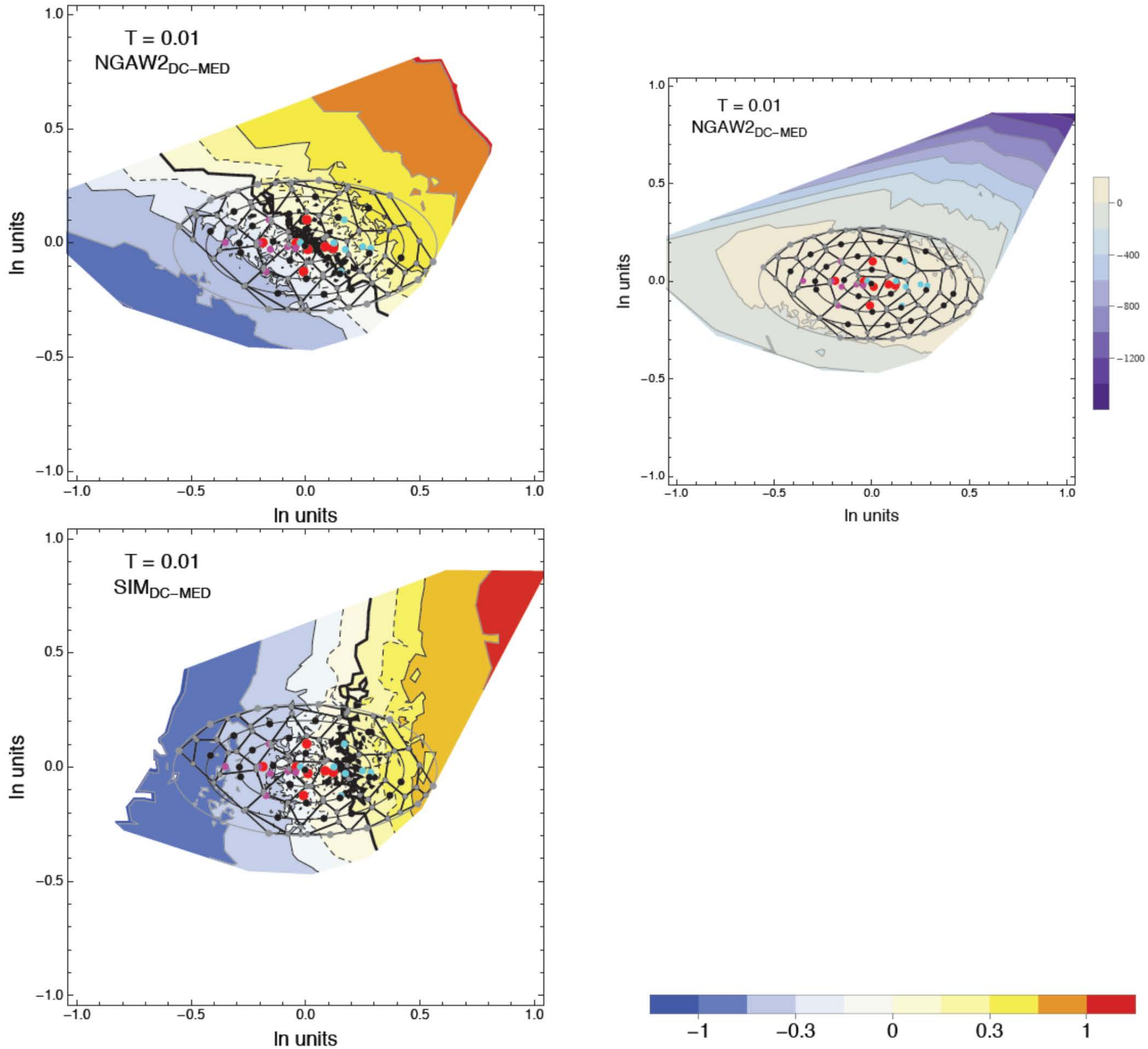
Simulations



Logic Tree Used for DCPP



DCPP used Voronoi cells, not regular grid

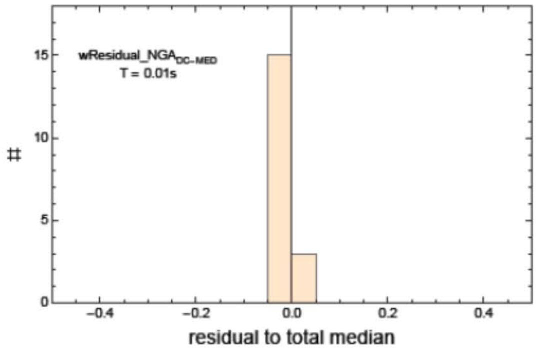


Select a representative model within each cell

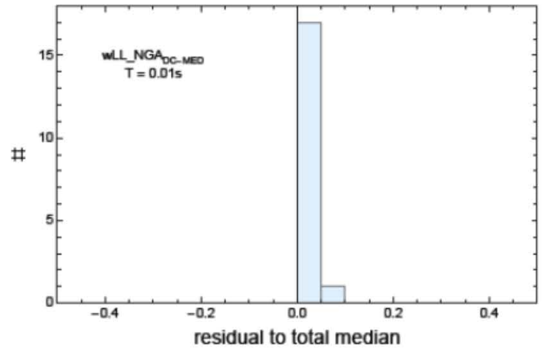
- Alternative Approaches
  - Choose Published GMPE in a cell
  - Choose model that is near center of cell
  - Choose model that is closest to the average model for the cell
  - Choose model closest to the mean hazard based on simplified but representative SSC – used by DCPP

Example Distribution of PGA

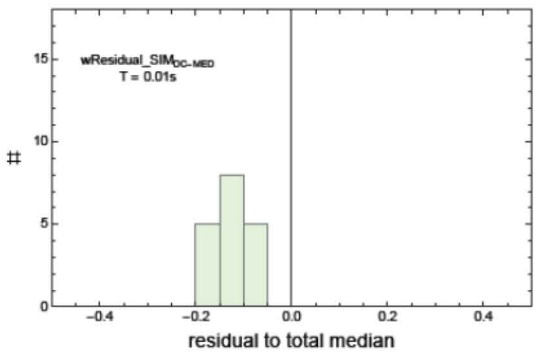
Mean
Resid
DC-MED



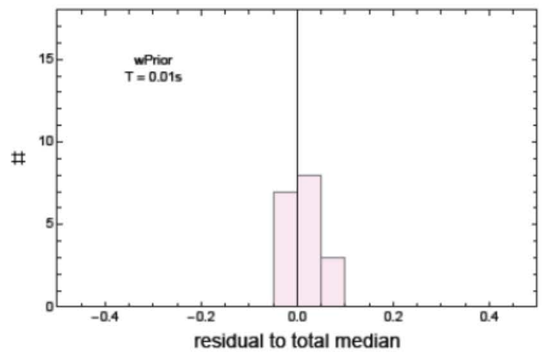
Likelihood
DC-MED



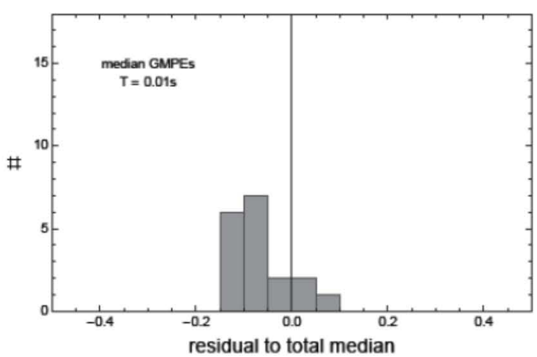
Mean
Resid
DC-SIM



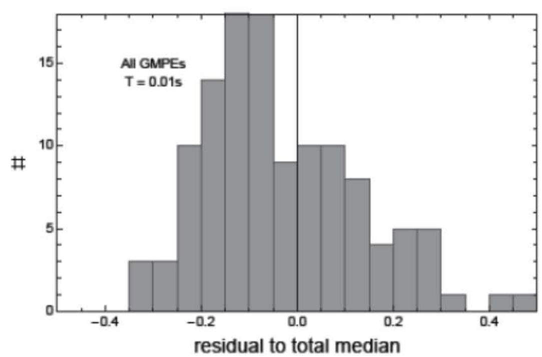
Prior
Density of
Generated
GMPE



Original
GMPEs

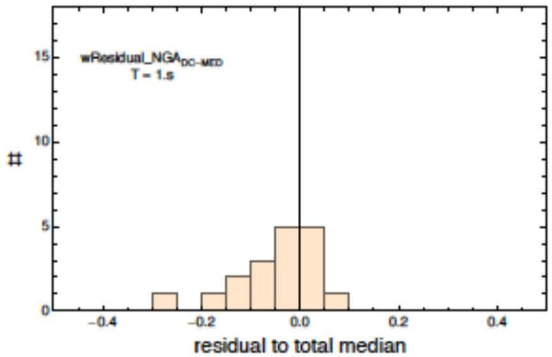


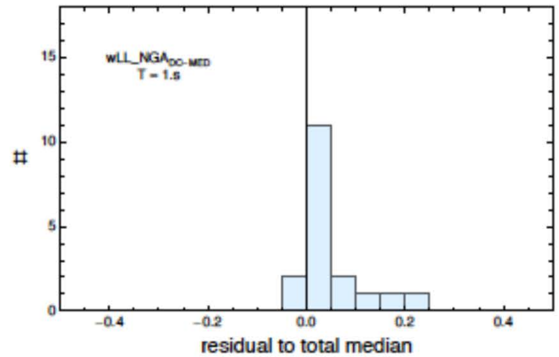
Original
GMPEs
+ Additional
Epistemic unc



Example Distribution of T=1

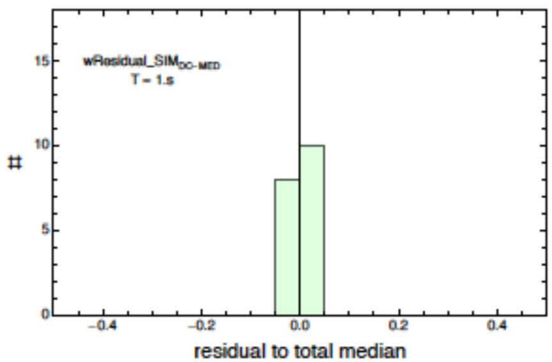
Mean
Resid
DC-MED

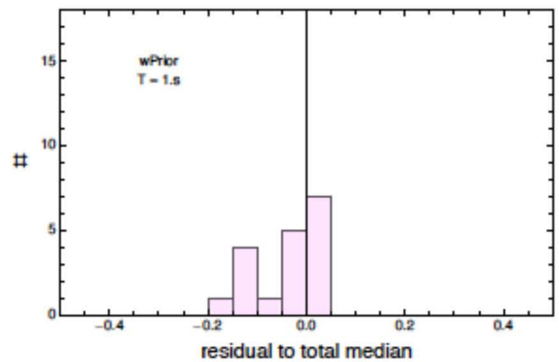




Likelihood
DC-MED

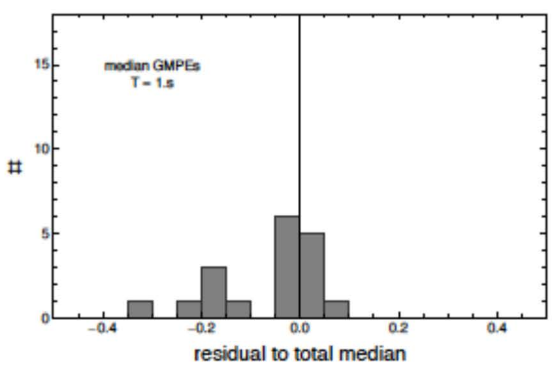
Mean
Resid
DC-SIM

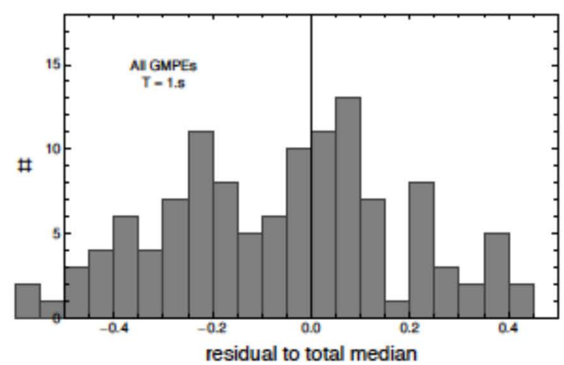




Prior
Density of
Generated
GMPE

Original
GMPEs





Original
GMPEs
+ Additional
Epistemic unc

Example of Selected Models (PGA, M5.5)

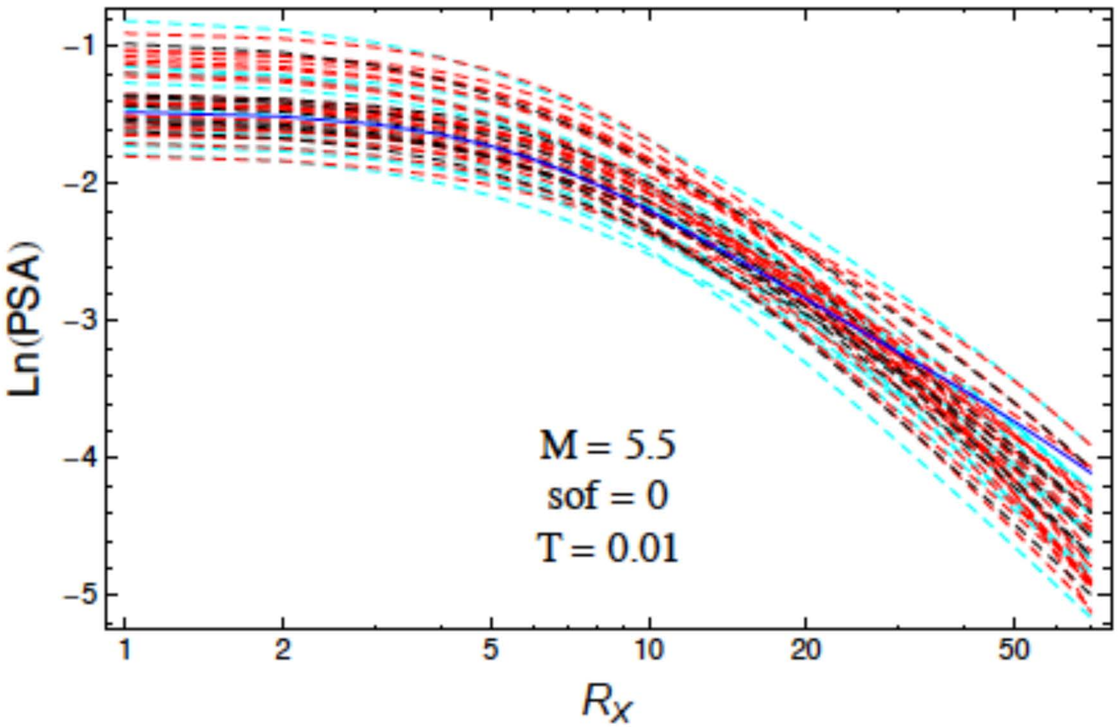
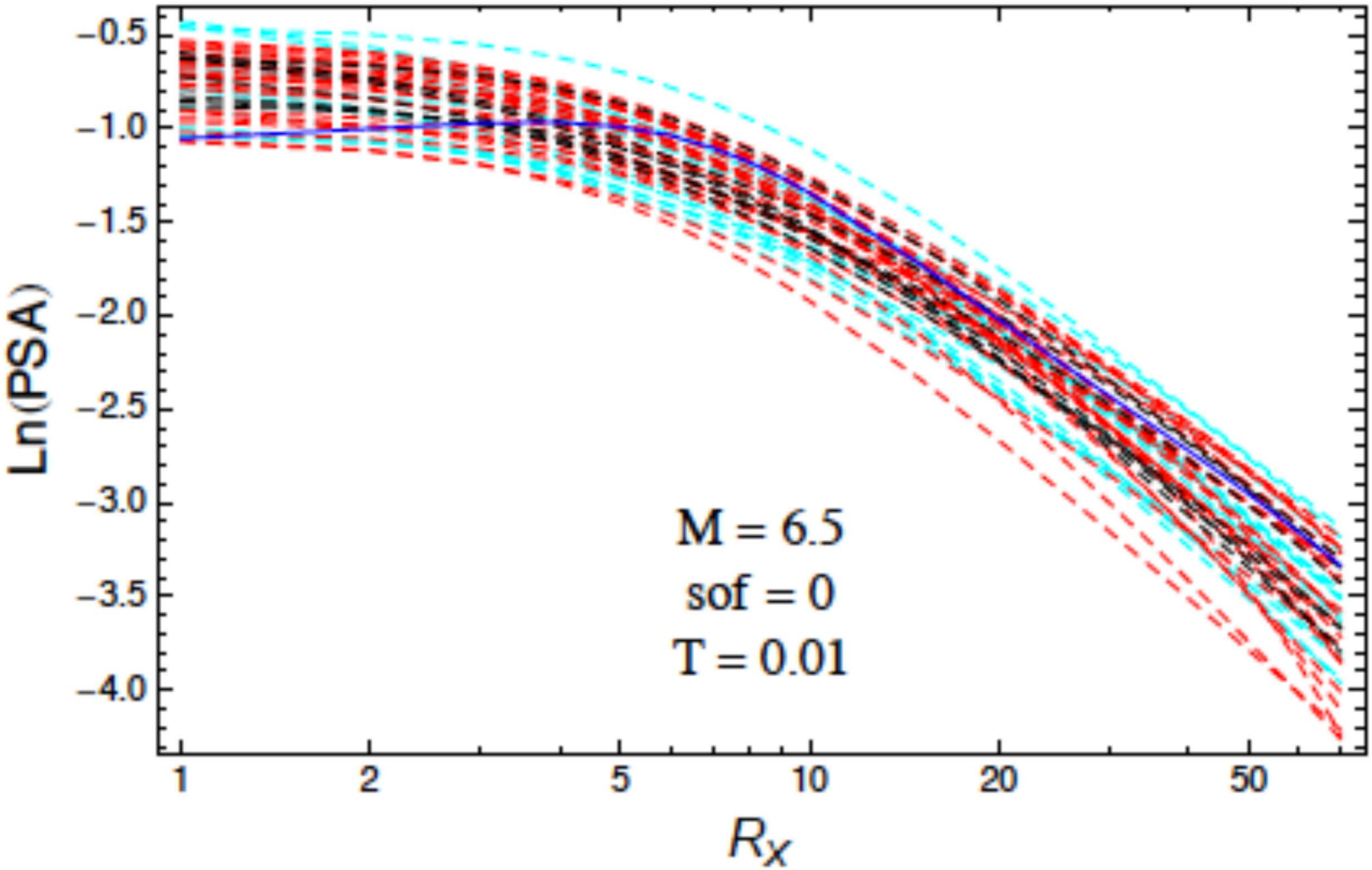
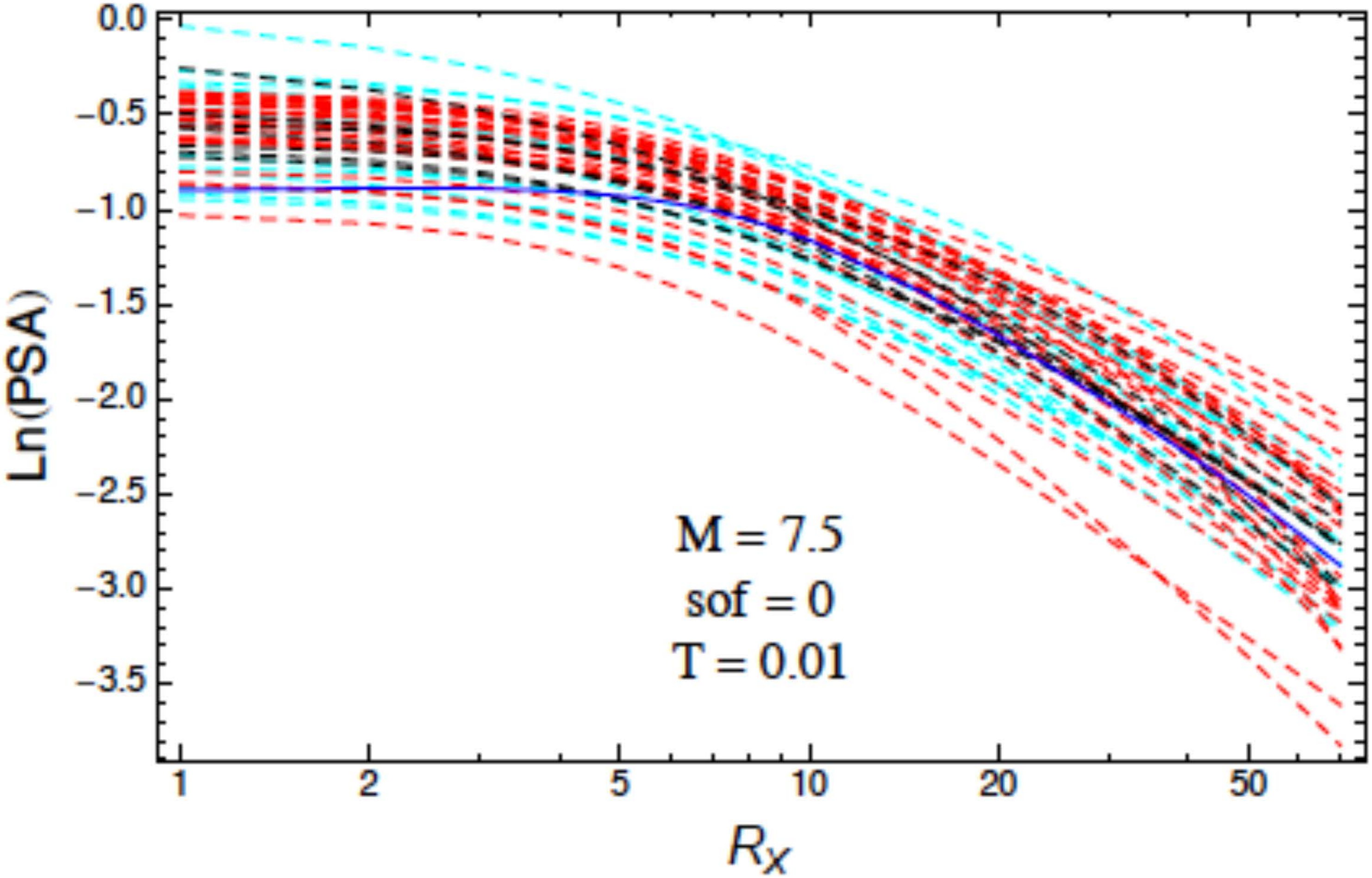


Figure 2.392: DCPPv4: Distance scaling of the original GMPEs (dashed black), the original GMPEs with uncertainty model (dashed cyan) and selected A models (dashed red) and the model of Graizer (2014) (blue), for a scenario with $M = 5.5$, $F = 0$, and $T = 0.01$s.

Example of Selected Models (PGA, M6.5)



Example of Selected Models (PGA, M7.5)



Decisions/Judgments made by TI Team using Sammon's maps

- Scenarios
  - Selection of scenarios
  - Selection of weights on the scenarios for computing Delta
- Data set for comparison
  - Selection of data sets
  - Weights on data sets if more than one is used
- Statistics for computing weights
  - Selection of statistics
    - 1/abs(mean Resid + C)
    - Likelihood (with fixed phi and tau)
    - Density of generated models (prior)
  - Method (weights) for combining these statistics into final weights

References

- Atkinson, G. M., J. Bommer, and N. Abrahamson (2014). Alternative Approaches to Modeling Epistemic Uncertainty in Ground Motions in Probabilistic Seismic-Hazard Analysis, Seism. Res. Let, 55 85(6): 1141-114
- GeoPentech (2015). Southwestern United States Ground Motion Characterization SSHAC Level 3 – Technical Report Rev.2, March 2015